





Report Documentation Page				Form Approved OMB No. 0704-0188	
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.					
1. REPORT DATE <b>JUL 2014</b>		2. REPORT TYPE		3. DATES COVERED <b>00-00-2014 to 00-00-2014</b>	
4. TITLE AND SUBTITLE <b>Initial Capabilities Documents: A 10-Year Retrospective of Tools, Methodologies, and Best Practices</b>				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) <b>Defense Acquisition University, 9820 Belvoir Rd Ste 3, Fort Belvoir, VA, 22060-9910</b>				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT <b>Approved for public release; distribution unlimited</b>					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT <b>Same as Report (SAR)</b>	18. NUMBER OF PAGES <b>35</b>	19a. NAME OF RESPONSIBLE PERSON
a. REPORT <b>unclassified</b>	b. ABSTRACT <b>unclassified</b>	c. THIS PAGE <b>unclassified</b>			

**Keywords:** *Initial Capabilities Document (ICD), Methodologies, Joint Capabilities Integration and Development System (JCIDS), Joint Acquisition, Capabilities-Based Assessment (CBA)*

# *Initial Capabilities Documents: A 10-Year Retrospective of Tools, Methodologies, and Best Practices*

 *Maj Bryan D. Main, USAF,  
Capt Michael P. Kretser, USAF,  
Joshua M. Shearer, and  
Lt Col Darin A. Ladd, USAF*

The Joint Capabilities Integration and Development System (JCIDS) is 10 years old and ripe for review. A central output document of the JCIDS process is an Initial Capabilities Document (ICD) used by the Department of Defense to define gaps in a functional capability area and define new capabilities required. The research team analyzed 10 years of ICDs to identify methods and trends. The team found that several methodologies were favored and a convergence emerged in format and necessary content. Additionally, potential shortfalls in current best practices of interest to implementers and decision makers are identified. Guidelines and best practices are presented to create more effective, concise, and complete ICDs.



It may come as a surprise to many acquisition practitioners that the historically unstable, formal written procedures and processes that embody the Defense Acquisition System and Joint Capabilities Integration and Development System (JCIDS) are now over 10 years old. During this time, the Department of Defense (DoD) has published significant revisions and updates to the JCIDS-related documents, including Department of Defense Instruction (DoDI) 5000.02 entitled, *Operation of the Defense Acquisition System* and the *Joint Capabilities Integration and Development System Manual* (DoD, 2013; Joint Requirements Oversight Council [JROC], 2012). The current system's longevity may be partially attributable to its utilization of modern management approaches, further enabled by a slow convergence of the Joint Strategic Planning System set in motion by the Goldwater-Nichols Act (Goldwater-Nichols, 1986). With its focus on Joint development and deconfliction of capabilities, JCIDS uses a portfolio management approach and streamlined documentation to elevate user requirements relatively quickly and vet them against current capabilities. Further, its emphasis on knowledge management ensures that all stakeholders can view the process and its outcomes as the key documents percolate through the JCIDS process.

Early analysis of the JCIDS process by the U.S. Government Accountability Office (GAO, 2008) identified variable product quality. Attempts were made at creating user's guides to improve document quality (JROC, 2012; Joint Chiefs of Staff [JCS], 2009); however, these documents did not fully address the analysis techniques contained therein. As a key component of process quality, the ability to select, use, and report an appropriate analysis technique is an item of interest for authors, stakeholders, and portfolio managers. Therefore, this effort reviewed the content, tools, and methodologies recorded in the past 10 years' Initial Capabilities Documents (ICDs) created as a part of the JCIDS process.

---

***Early analysis of the JCIDS process by the U.S. Government Accountability Office (GAO, 2008) identified variable product quality.***

---

As one of the first products created in JCIDS, ICDs are important because they validate requirements derived through an analysis of current capabilities and capability gaps. Additionally, they are signed by senior service members and are the basis for program acquisitions. Further, due to their recommended brevity, it is important that ICDs contain the correct level of detail to identify the key assumptions, limitations, and boundary conditions contained or referenced in their analyses. A lack of analytical clarity at this stage may lead to misdirected resources further in the process (GAO, 2008).

Of particular interest were the methodologies that implementers and decision makers were choosing to use in developing ICDs. Through this process, it was possible to identify a series of best practices and guidelines to improve ICD quality, and thus aid in the evolution of JCIDS.

## Background

The JCIDS process was created as a response to a 2002 memorandum from the Secretary of Defense to the Vice Chairman of the Joint Chiefs of Staff to study alternative ways to evaluate requirements (JCIDS, 2014). At the time of this memorandum, the governing document was Chairman of the Joint Chiefs of Staff Instruction 3170.01B (CJCSI, 2001) and was titled the Requirements Generation System. The purpose of JCIDS was to streamline and standardize the methodology to identify and describe capabilities' gaps across the DoD, and to engage the acquisition community early in the process while improving coordination between departments and agencies.

The GAO's (2008) report indicated that "the JCIDS process has not yet been effective in identifying and prioritizing warfighting needs from a joint, department-wide perspective" (GAO, 2008, para. 1). This report outlined the shortfalls and gaps in the JCIDS process in its 5-year life span, furthering the redesign of the process. Additionally, the report outlined several recommendations for the DoD, including developing a more analytical approach within JCIDS to better prioritize and balance capability needs as well as allocating the appropriate resources for capabilities development planning.

The current documentation for both creating and implementing ICDs are the *Capabilities-Based Assessment (CBA) User's Guide* and the *JCIDS Manual*. These documents were released in 2009 and 2012 respectively

as a part of the process to address the issues found by the 2008 GAO report. The impact of these documents in improvements to the JCIDS process has yet to be determined, but will be discussed in this article.

## Focus and Methodology

The research team used the Knowledge Management/Decision Support (KM/DS) system to examine the JCIDS process. The KM/DS Web site is the repository for the documents created through or as a byproduct of the JCIDS process. Included in this study are ICDs, Joint Capabilities Documents (JCDs), Capability Development Documents, and other supporting documents that are a part of this process. To focus this research, the team specifically studied the core documents—ICDs and JCDs—to better understand what kinds of methodologies are being implemented by the various Services to convey the gap information under study.

---

*Ultimately, it was the intention of the research team to observe and report on best practices for future ICD writers.*

---

Of those entered in the KM/DS system, over 1,000 ICDs and JCDs were in various phases of the JCIDS process covering the period January 1, 2002, to December 31, 2012. The team decided to focus on only those documents that were considered ‘Validated’ and ‘Final,’ with the expectation of little to no revision remaining for these documents in the near future. These criteria reduced the number of the documents under review to 225 ICDs/JCDs. The team of four researchers split the ICDs/JCDs evenly across year and type to ensure similar exposure to the complete population available. At the completion of the review, the researchers met and discussed commonalities and anomalies found in documents of interest, and in the population in general. For purposes of this article, the term ICD will be used to describe both the ICDs and JCDs unless specified otherwise.

The team formulated an initial set of generally accepted methodologies for a baseline to identify, categorize, and sort the currently used methodologies within the ICDs. They did not solely consider this set of techniques, but allowed for an expansion of the list to detect emergent techniques.

Additionally, an analysis was performed on key metrics and areas of interest to see if there were any correlations or observations that could be made about various components of the ICDs. These attributes were chosen as they were key areas of interest or sections in the *Capabilities-Based Assessment (CBA) User's Guide* and the *JCIDS Manual*. By examining these attributes, the team was able to determine to what extent past ICDs have followed current guidance. Some of the components considered in the analysis can be found in Table 1.

TABLE 1. ATTRIBUTES FOR ANALYSIS

Attributes			
ACAT Level	DOTMLPF-P Analysis	Measures of Effectiveness	Threshold Values Defined
Lead FCB	Formatting	UJTL Traceability	Objective Values Defined
Supporting FCBs	Analysis Described	Number of Gaps	Number of Pages
Current Milestone	Capabilities Defined	Gap Prioritization	Attributes Listed

Note. ACAT = Acquisition Category; DOTMLPF-P = Doctrine, Organization, Training, Materiel, Leadership, Personnel, Facilities – Policy; FCB = Functional Capabilities Board; UJTL = Universal Joint Task List.

Ultimately, it was the intention of the research team to observe and report on best practices for future ICD writers. As such, we focused on finding those ICDs that best embodied the intentions found in the *Capabilities-Based Assessment (CBA) User's Guide* (JCS, 2009) and the *JCIDS Manual* (JROC, 2012).

Results

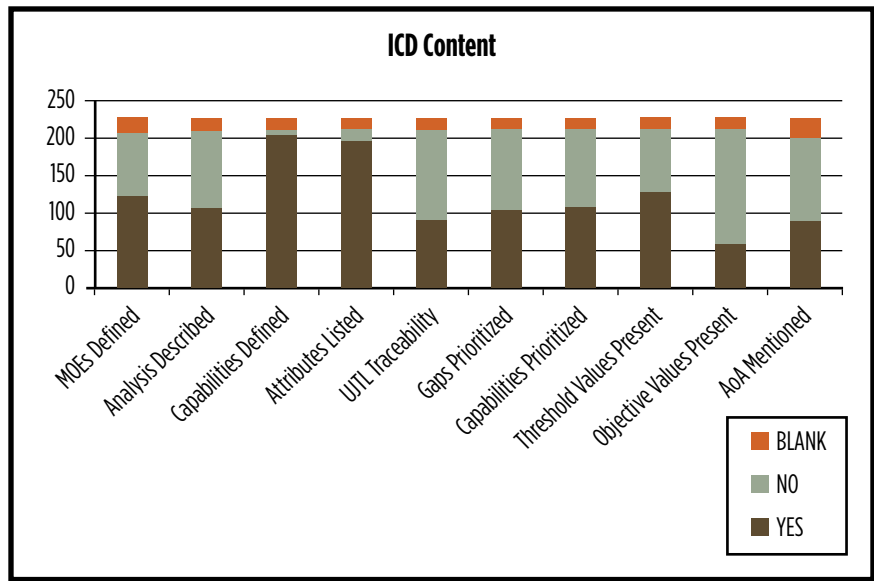
The team examined several ICD characteristics that are presented in the *JCIDS Manual* and were expected to be used in most ICDs (Figure 1). The team found that of the features prescribed by the *JCIDS Manual*, many were not present in the majority of ICDs reviewed. Less than half of the ICDs described what analysis was done to identify capability gaps. Over 90 percent of the ICDs reviewed define a specific capability while some ICDs do not have a well-defined end state.



Nearly half of the ICDs analyzed defined their Measures of Effectiveness (MOE), described their analysis, prioritized gaps and capabilities, and defined minimum values for required capability attributes. The presence of these characteristics provides additional information to the reader and improves the fidelity of the ICD; their absence leaves commonly questioned areas open for discussion. The 2012 *JCIDS Manual* requires threshold values, but description of the analysis has been left open to the document creator, and many choose not to describe it. In fact, the manual states a preference to “avoid unnecessary rigor and time-consuming detail.” Applying and documenting some level of rigor seems necessary and useful for documenting how gaps were identified and showing how the capability requirements were justified. The prioritization of gaps and capabilities helps decision makers understand those components that are critical when resources are limited to address the full capability gap, but allows for partial capability fulfillment or a subset of smaller gaps to be filled.

The inclusion of an Analysis of Alternatives (AoA) is an interesting additional piece of content as it is no longer part of the *Capabilities-Based Assessment (CBA) User’s Guide*, and is done in subsequent work of the

FIGURE 1. ICD CONTENT ANALYSIS

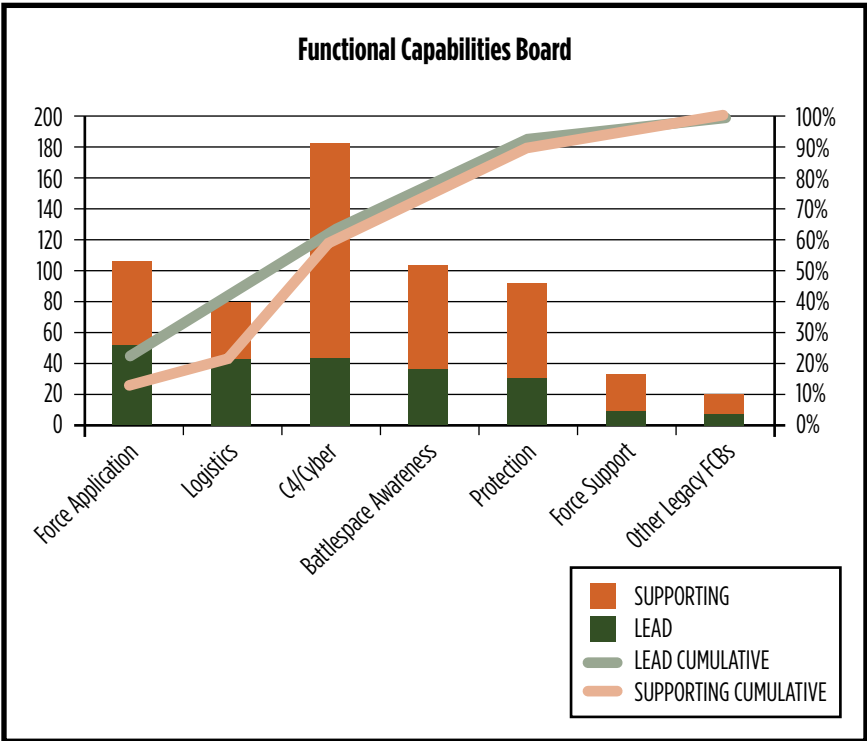


Note. AoA = Analysis of Alternatives; MOEs = Measures of Effectiveness; UJTL = Universal Joint Task List.

JCIDS process. Nearly one-third of all ICDs included some form of an AoA, whether in the form of a brief paragraph or a full documentation found in attachments or enclosures. Most documents that contained a complete AoA were from the first 5 years, a period of time in which the content of ICDs was still in flux. Including an AoA would presuppose a preferred materiel solution—something not within the scope of documenting a capability gap.

Also, less than 25 percent of the ICDs surveyed contained objective values for the capabilities to be met. While it has become more common for threshold values to be defined for capabilities, objective values can only be seen in less than half of those cases. One might expect to see objective values used more frequently to quantify desired capabilities beyond the minimums. Including objective values is expected to aid the process owner in determining if a recommended solution is able to meet the objective of closing the specified gap.

**FIGURE 2. NUMBER OF FUNCTIONAL CAPABILITIES IN ICDs ANALYZED**

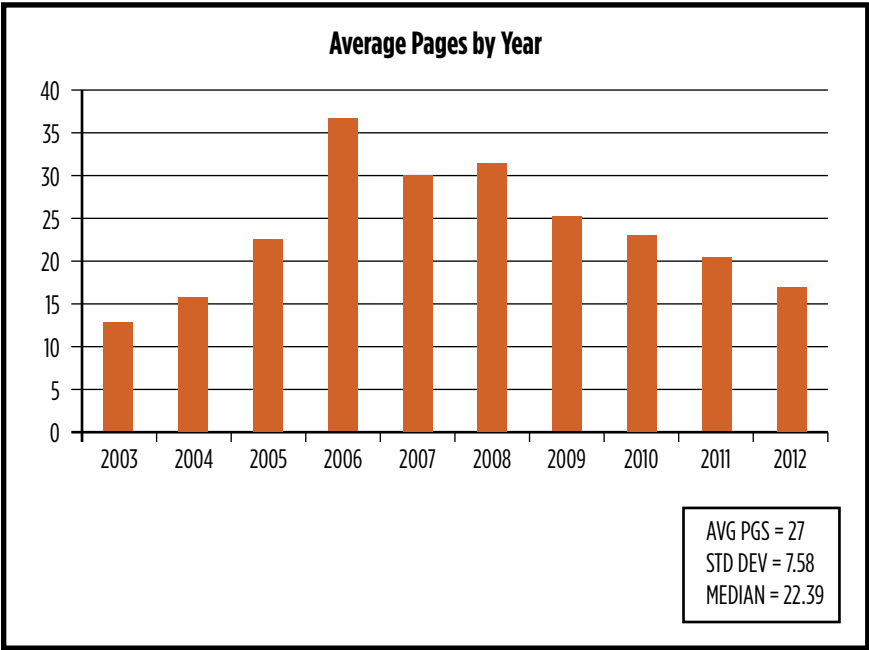


Note. C4 = Command, Control, Communications, and Computers; FCBs = Functional Capabilities Boards.

Identifying the Functional Capabilities Boards (FCBs) to which ICDs were assigned provided insight as to what types of capabilities have been defined and what priorities have been dictated. FCB and associated Joint Capability Area (JCA) categories include Force Support (formerly Force Support and Building Partnerships); Battlespace Awareness; Force Application; Logistics; Command, Control, Communications, and Computers (C4)/Cyber (formerly Net-Centric, Command and Control, and C4/Cyber); and Protection. Previous FCBs, including Special Operations and Test, are listed in Figure 2 under “Other Legacy FCBs.”

*Identifying the Functional Capabilities Boards (FCBs) to which ICDs were assigned provided insight as to what types of capabilities have been defined and what priorities have been dictated.*

**FIGURE 3. AVERAGE NUMBER OF PAGES FOR ICDs IN CORRESPONDING YEARS**



Note. Avg = Average; Dev = Deviation; Std = Standard.

Each ICD is assigned a lead and supporting FCB. Figure 2 shows ICDs arranged by lead FCB with Force Application being the most prominent lead FCB. The prominence of Force Application over Force Support led the team to conclude that validated ICDs are more likely to focus on the direct needs of the warfighter and less likely to focus on capabilities of supporting processes. At the same time, a significant number of ICDs listed net-centricity and C4/Cyber as supporting FCBs.

The research team decided early on to capture the length of ICDs as the *Capabilities-Based Assessment (CBA) User's Guide* specifically states that ICDs should be no longer than 10 pages, with separate allowance for appendices (JCS, 2009). Figure 3 presents the average ICD page length without appendices; quality and meticulousness were not necessarily correlated with quantity of pages. ICDs were meant to be concise documents that outline the necessary capabilities while still answering the required content.

The drastic increase in length of ICDs is potentially a result of a change in the process by which capability gaps were outlined. As with most processes, uncertainty in a new method allows for an increase in the breadth and depth of the information found within ICDs. As page length has been steadily decreasing over the last few years, it would suggest that sponsors have become more comfortable with the process and have become more efficient at outlining the information needed.

One final note concerning page length was to evaluate the relation of page length to Acquisition Category (ACAT) level. Would larger projects lend themselves to taking more pages to explain the research and identify the gaps? These two factors were examined, and between ACAT Levels I, II, and III the mean page length was 25.53, 23.35, and 21.02 respectively. While the difference between ACATs I and III are statistically significant using a t-test with an alpha of .05, the difference (on average) is roughly four pages.

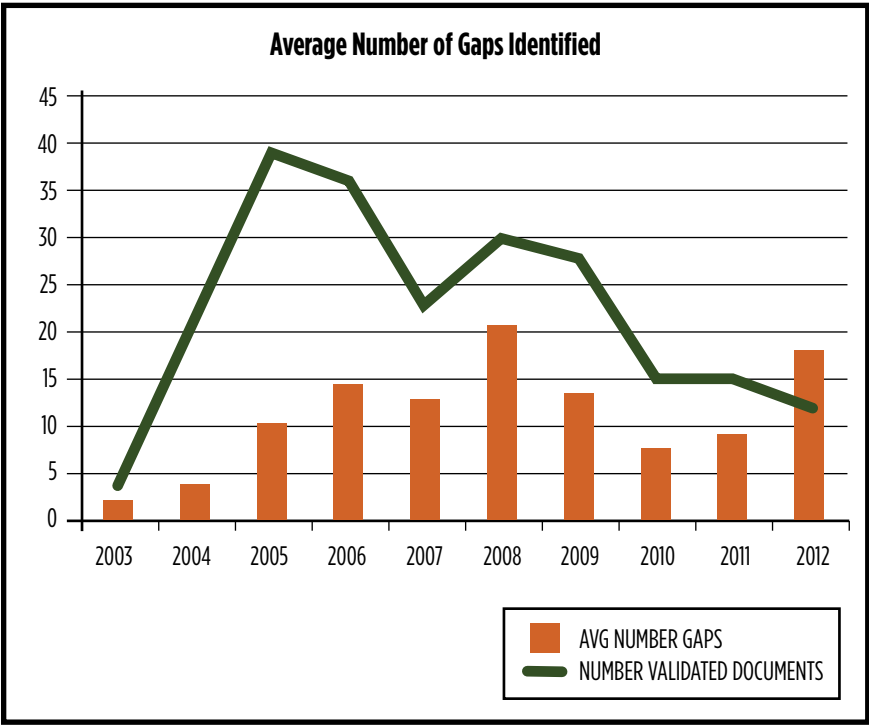
Within the time period analyzed, a total of 2,779 gaps were identified; the average number of gaps identified in an ICD are shown in Figure 4. Additionally, Figure 4 illustrates the fluctuation in the number of ICDs validated each year. The GAO (2008) report noted that JCIDS was ineffective in properly prioritizing capabilities and suggested that nearly all ICDs submitted were accepted. Since the inception of the JCIDS process, 2012 was the first year that the average number of gaps exceeded number of ICDs validated. This suggests that ICDs are identifying more gaps per document, creating documents that are tackling larger and

more complex problems than before. It appears that the JCIDs process has matured, and the process has become more efficient as a result of the GAO report.

The research team noted that many ICDs had “too few” gaps identified (only one or two, or none at all) leading to the conclusion that the methodology employed was not optimal as there are probably more gaps that have yet to be identified, and several documents identified “too many” gaps. It was very difficult to understand and prioritize identified gaps when too many were identified (several contained over 50 gaps).

Figure 5 is a representation of the most frequently used methodologies from 2002 to 2012, displaying the percentage of ICDs covered by the methodology. The top five methodologies were chosen for representation as they represented those methodologies that were implemented in greater than 10 percent of ICDs, whereas the remaining methodologies were typically used in one to two ICDs only. Each ICD employed

**FIGURE 4. AVERAGE NUMBER OF GAPS IDENTIFIED COMPARED TO NUMBER OF VALIDATED DOCUMENTS**

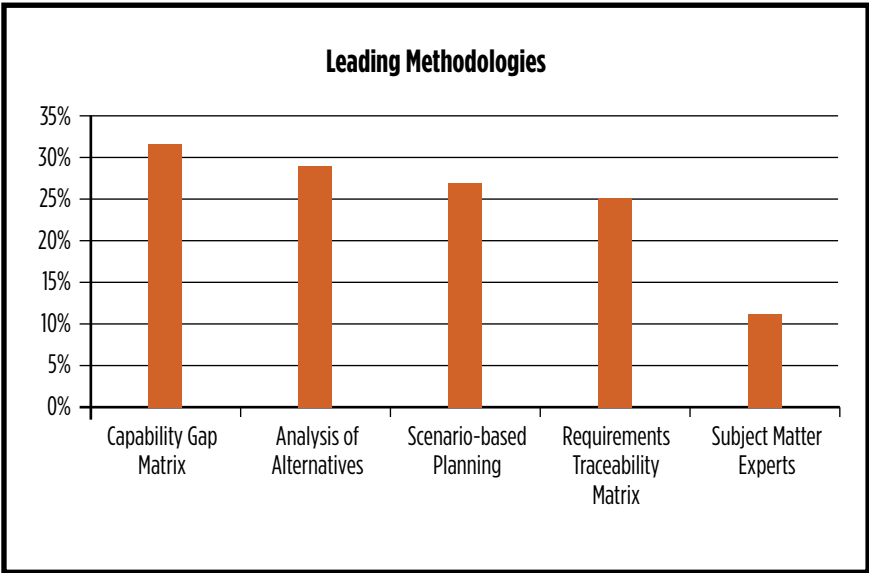


several methodologies so the percentages will not sum to 100 percent. A variety of analytical techniques may be appropriate depending on the type of analysis being conducted. As an example, intelligence-based assessment would likely be an appropriate technique for identifying a strategic capability gap requiring a new weapon system, but not appropriate for identifying the need for a new inventory system for the Defense Commissary Agency.

**Doctrine, Organization, Training, Materiel, Leadership, Personnel, Facilities-Policy**

The research team observed at least two interpretations of the Doctrine, Organization, Training, Materiel, Leadership, Personnel, Facilities-Policy (DOTMLPF-P) analysis within the ICDs. The analysis sometimes took the course where ICDs identified DOTMLPF-P categories of nonmateriel solutions that could satisfy capability gaps, while others took the second interpretation where ICDs considered the DOTMLPF-P implications of their proposed materiel solution. Defense Acquisition University training for DOTMLPF-P distinguishes between these uses and indicates that the ICD should focus on the former approach as the latter is addressed in later stages of the acquisition process (Defense Acquisition University, 2014).

**FIGURE 5. TOP METHODOLOGIES USED**



We also observed a wide range of quality in these analyses. Many ICDs contained rote statements declaring the insufficiency of these non-materiel approaches to close capability gaps. To paraphrase an example, several ICDs stated that “DOTMLPF solutions were considered..., but adjustments or improvements in these areas will have minimal impact to mission satisfaction.” Though not every capability gap can be met with nonmateriel solutions, such “box check” DOTMLPF-P analyses offer no value to the requirements validation process.

3 In contrast, several analyses reflected a concerted effort to find nonmateriel solutions to supplement the proposed materiel solution. One example of this level of analysis is the Air Force’s Advanced Pilot Training ICD. In its DOTMLPF-P analysis, the Service employed a three-phase process: first, brainstorming and combining possible solutions; second, conducting quantitative analysis on a subset of the best of the proposed solutions; and third, conducting a qualitative assessment of the final list of proposed solutions. Not all of the nonmateriel solutions were deemed feasible or prudent, but several were included as part of the final recommendations. Further explanations of how the Air Force conducted this analysis are found in the ICD and its attachments on KM/DS.

## Recommendations and Guidelines

Through the analysis the team observed a variety of interpretations of how to write an ICD. In general, analytical rigor could be stronger. In a fiscally constrained environment, the importance of documenting analysis is magnified, and many ICDs fell short of careful documentation of analysis. Another observation is that most of the ICDs were submitted by the Services and very few by Joint sponsors. This is not surprising as individual Services organize, train, and equip their forces; it is expected that capability gaps will continue to be identified by the Services.

### Useful Analytical Techniques

Several ICDs utilized subject matter experts (SMEs) to identify capability gaps and recommend solutions. One way to incorporate SME input into a more rigorous fashion is by employing the Delphi Technique. In this method, the researcher works with 10-15 experts to identify, further define, and determine the importance of an issue in their area of expertise (Linstone & Turoff, 1975). Using the Delphi method when SMEs are available is one way to add analytical rigor to the ICD process.

Though not possible for all ICDs, several documents included a life-cycle cost summary that was effective in communicating the costs of the capability gap. If the proposed solution is expected to reduce some recurring cost, presenting those numbers can make a convincing case to the reader.

In the Appendix to this article, the authors provide a list of additional analytical techniques along with a short description of each. This resource is intended to assist ICD writers and project managers in selecting a methodology or methodologies appropriate for their document or project. References are provided to direct interested readers to source documents with additional descriptions of each methodology.

---

***One way to incorporate SME input into a more rigorous fashion is by employing the Delphi Technique. In this method, the researcher works with 10-15 experts to identify, further define, and determine the importance of an issue in their area of expertise (Linstone & Turoff, 1975).***

---

### **Architectural Enhancements**

Nearly all existing ICDs present a High-Level Operational Concept Graphic (OV-1) depicting the proposed solution(s). A previous Air Force Institute of Technology researcher identified several additional Department of Defense Architecture Framework (DoDAF) products that could be useful to present within the ICD (Hughes, 2010). The Capability Taxonomy (CV-2), Capability Dependencies (CV-4), Capability to Operational Activities Mapping (CV-6), as well as the Operational Resource Flow Description (OV-2) and Operational Activity Decomposition Tree (OV-5a) are products now required by JCIDS for the ICD.

Hughes also found value in including the Operational Activity Model (OV-5b) and Operational Activity to Systems Function (SV-5). The OV-5b presents capabilities and activities and their relationship among activities,

inputs, and outputs. The SV-5 maps systems back to capabilities or operational activities. Neither is currently recommended in the *JCIDS Manual*, but could be presented there as optional architecture products.

### Characteristics of Model ICDs

Based upon analysis of the data that were examined during the study, several guidelines or best practices emerged. The best written ICDs provided detailed, but relevant analysis without being too wordy. Here, we propose the contents of a model ICD.

The most fundamental building block of an ICD is conformance to JCIDS standards of format and content. The *JCIDS Manual* presents a logical flow of the document from gap identification to final recommendations. The Concept of Operations should illustrate how the described capability will support the Joint Force Commander. The JCAs or Universal Joint Task List pedigree should be clear, but not overly detailed. Documents that rolled up capability gaps to Tier 2 or Level 2 components seemed more readable than those that traced capabilities to lower levels. A document that acknowledges extant systems is more convincing in establishing a capability gap.

The team believes that a concise ICD may be written with 5–12 gaps identified. Page lengths may vary by ACAT level, with more complex proposed solutions demanding more explanation, but the ideal ICD would be 15–25 pages in length. In short, a well-written ICD will follow the prescribed format, clearly define its necessity to the Joint mission, and be presented in a clear and logical manner. Additionally, the ICD should present clear MOEs with minimum and desired values. Good MOEs allow the reader or evaluator to know when the new capability has delivered on its design promises. MOEs are sometimes confused with measures of performance (MOPs). Noel Sproles states, “MOEs are concerned with the emergent properties or outcomes of a solution. They take an external view of a solution and as such are different from MOPs, which are concerned with the internal workings of a solution” (Sproles, 2002).

Table 2 compares ICD content required by the *Capabilities-Based Assessment (CBA) User's Guide*, the *JCIDS Manual*, and recommendations based on our analysis. As part of the analysis, the team identified those ICDs that implemented and followed the best practices identified by the team. These ICDs, shown in Table 3, are identified to give future

ICD writers and functional groups examples of what they can strive toward to make clear and concise documents that are both effective and efficient.

Future Research and Conclusions

Future research could focus on the relationship between the ICD and the program it generates. Can the utility or performance of a program be traced to the description of the initial capability gap and

TABLE 2. COMPARISON OF CBA/ICD CONTENT

<i><b>CBA User's Guide</b></i>	<i><b>JCIDS Manual</b></i>	<i><b>Research Team</b></i>
Purpose	CONOPS/Desired Outcomes	CONOPS
Background/Guidance	Joint Functional Areas	Relationship to Tier 2 JCA/UJTL
Objectives	Description of Required Capability Gaps, Overlaps, Redundancies	Analysis Techniques Used with Description of Scope
Scope	Capability Attributes/Metrics	Prioritized List of 5-12 Capability Gaps
Methodology -Approaches -MOEs -Technological/Policy Opportunities	Relevant Threats/Operational Environment	Clearly Defined MOEs with Threshold and Objective Values
Organization/Governance	Proposals for Non-materiel Solutions	DOTMLPF-P Analysis of Nonmateriel Solutions
Projected Schedule	Final Recommendations	Clear Final Recommendations
Responsibilities		

*Note.* CBA = Capabilities-Based Assessment; CONOPS = Concept of Operations; DOTMLPF-P = Doctrine, Organization, Training, Materiel, Leadership, Personnel, Facilities - Policy; ICD = Initial Capabilities Document; JCA = Joint Capabilities Assessment; JCIDS = Joint Capabilities Integration and Development System; MOEs = Measures of Effectiveness; UJTL = Universal Joint Task List.

TABLE 3. SAMPLE OF EXEMPLARY ICDs

Document Name (Control Number)	Year	Noteworthy Items
Data Masked (05-51947485-00)	2005	Layered analytical methods resulted in 100 shortfalls that were further clustered and examined-top 3 presented for further study
Military Operational Medicine (07-65416952-00)	2007	Extensive Doctrine, Organization, Training, Materiel, Leadership, Personnel, Facilities (DOTMLPF); lots of prioritized tables
Aviation Ground Support (07-600735309-00)	2007	Prioritized tables, quantitative threshold values, good DOTMLPF, multiple methods used to determine/rank nonmateriel solutions
Initial Capabilities Document for Joint Improvised Explosive Device Defeat (07-66686002-00)	2007	Performed a well-documented, thoughtful DOTMLPF analysis; references three assessments—Joint Staff (J8), Joint Improvised Explosive Device Defeat Task Force baseline, and follow-on; prioritized tables
Biometrics in Support of Identity Management (09-090146111-00)	2008	Detailed analysis including Scenario-based Planning and Risk Analysis
Advanced Pilot Training (10-99164267-00)	2009	Strong DOTMLPF analysis; clear explanation of analytical approach included in Appendices
Vessel-to-Shore Bridging (09-97169105-00)	2009	Gaps have numerous subparts; uses a typical but good example of capability prioritization/mapping matrix (includes Measures of Effectiveness [MOE] and Minimum Values)

TABLE 3. SAMPLE OF EXEMPLARY ICDs (CONTINUED)

Document Name (Control Number)	Year	Noteworthy Items
Cross Domain Enterprise (10-112959174-00)	2010	Uses a typical but good example of capability prioritization/mapping matrix (includes MOEs and Minimum Values); recommends mix of materiel and nonmateriel solutions
Amphibious Combat Vehicle ICD (11-151956055-00)	2011	Requirements traceable to the Joint Operating Concept vice Universal Joint Task Lists; uses a typical, but good example, of capability prioritization/mapping matrix (includes MOEs and minimum values); recommends mix of materiel and nonmateriel solutions
Personnel Recovery (12-167465473-00)	2012	Succinct document; recommends materiel and nonmateriel solutions
Data Masked (12-159990107-00)	2012	Detailed analysis using several techniques; well-defined MOEs including Threshold and Objective Values

requirement definition? Are there characteristics of an ICD that indicate how well a program will adhere to cost, performance, and schedule expectations?

Since 2002, the JCIDS process has been refined and enhanced. There appears to be a convergence in the formatting and content of many ICD/JCDs since 2008. While the quality of historical ICDs varies, marked improvements to the analysis have been documented since 2008, possibly due to the GAO report from the same year.

Through research of the current methodologies used in ICDs since the inception of the process, the research team has formulated an outline of proposed areas upon which writers and implementers can focus. Future writers may use this outline as well as a series of DoD guidelines to provide the Joint community with superior ICDs that achieve their goals in a more efficient manner with minimal processing time.

## Author Biographies



**Maj Bryan D. Main, USAF**, is currently studying at the Air Force Institute of Technology for a Doctor of Philosophy degree in Logistics. He holds a bachelor's degree in History from John Brown University, and a master's degree in Logistics Management from the Air Force Institute of Technology.

*(E-mail address: Bryan.Main@us.af.mil)*



**Capt Michael P. Kretser, USAF**, is currently studying at the Air Force Institute of Technology for a Doctor of Philosophy degree in Logistics. He holds a bachelor's degree in Computer Science Programming from Limestone College, and a master's degree in Logistics Management from the Air Force Institute of Technology.

*(E-mail address: Michael.Kretser@us.af.mil)*



**Mr. Joshua M. Shearer, USAF**, is currently studying at the Air Force Institute of Technology for a Doctor of Philosophy degree in Systems Engineering. He holds a bachelor's and master's degree in Materials Science and Engineering from Wright State University and a master's degree in Business Management from Wright State University.

*(E-mail address: Joshua.Shearer@us.af.mil)*



**Lt Col Darin A. Ladd, USAF**, is the director of Communications and assistant professor of Systems Engineering at the Air Force Institute of Technology. As a consultant, he assisted Services and combatant commands with early systems analysis and systems selection projects. He holds a PhD from Washington State University in Information Systems, an MS in Information Resource Management from the Air Force Institute of Technology, and a BS from the U.S. Air Force Academy.

*(E-mail address: [Darin.Ladd@us.af.mil](mailto:Darin.Ladd@us.af.mil))*

## References

- Air Force Materiel Command. (2008). *Analysis of alternatives (AoA) handbook*. Office of Aerospace Studies. Retrieved from <https://acc.dau.mil/CommunityBrowser.aspx?id=45041>
- Barney, J. B. (1991). Firm resources and sustained competitive advantage. *Journal of Management*, 17(1), 99-120.
- Blanchard, B. S., & Fabrycky, W. J. (2010). *Systems engineering and analysis* (5th ed.). Upper Saddle River, NJ: Prentice Hall.
- Brosh, I. (1985). *Quantitative techniques for managerial decision making*. Reston, VA: Reston Publishing.
- Chairman of the Joint Chiefs of Staff. (2001). *Requirements generation system* (CJCSI 3170.01B). Retrieved from [https://info.aiaa.org/tac/SMG/SOSTC/Launch percent20Management percent20Documents/Appendix percent20B percent20Reference percent20Documents/Charman\\_JCS\\_Instruction.pdf](https://info.aiaa.org/tac/SMG/SOSTC/Launch%20Management%20Documents/Appendix%20B%20Reference%20Documents/Charman_JCS_Instruction.pdf)
- Daszykowski, M., Kaczmarek, K., Vander Heyden, Y., & Walczak, B. (2007). Robust statistics in data analysis—A review: Basic concepts. *Chemometrics and Intelligent Laboratory Systems*, 85(2), 203-219.
- Defense Acquisition University. (2014). *DOTmLPF-P change recommendation*. Retrieved from <https://dap.dau.mil/acquipedia/Pages/ArticleDetails.aspx?aid=0f017b62-6273-4d58-b02c-d72c776198e8>
- Department of Defense. (2013). *Operation of the Defense Acquisition System* (Interim DoDI 5000.02). Washington, DC: Deputy Secretary of Defense.
- Goldwater-Nichols Department of Defense Reorganization Act of 1986, Pub. L. 99-433 (1986).
- Goodman, C. M. (1987). The Delphi technique: A critique. *Journal of Advanced Nursing*, 12(6), 729-734.
- Government Accountability Office. (2007). *Best practices: An integrated portfolio management approach to weapon system investments could improve DoD's acquisition outcomes* (Report No. GAO-07-388). Washington, DC: Author.
- Government Accountability Office. (2008). *Defense acquisitions: DOD's requirements determination process has not been effective in prioritizing joint capabilities* (Report No. GAO-08-1060). Retrieved from <http://www.gao.gov/assets/290/281695.pdf>
- Hammond, J. S., Keeney, R. L., & Raiffa, H. (1998). Even swaps: A rational method for making trade-offs. *Harvard Business Review*, 76, 137-150.
- Helms, M. M., & Nixon, J. (2010). Exploring SWOT analysis-where are we now? A review of academic research from the last decade. *Journal of Strategy and Management*, 3(3), 215-251.
- Hiam, A. (1990). *The vest-pocket CEO: Decision-making tools for executives*. Prentice Hall Press.
- Hughes, R. C. (2010). *Development of a concept maturity assessment framework*. Wright-Patterson AFB, OH: Air Force Institute of Technology.
- Joint Capabilities Integration and Development System (JCIDS). (2014). In Defense Acquisition University *ACQuipedia* online encyclopedia. Retrieved from <https://dap.dau.mil/acquipedia/Pages/ArticleDetails.aspx?aid=12227505-ba29-41c0-88f0-682a219d5bbc>

- Joint Chiefs of Staff. (2009). *Capabilities-Based Assessment (CBA) User's Guide* (Ver. 3). Force Structure, Resources, and Assessments Directorate (J8). Retrieved from [http://www.dtic.mil/futurejointwarfare/strategic/cba\\_guidev3.pdf](http://www.dtic.mil/futurejointwarfare/strategic/cba_guidev3.pdf)
- Joint Requirements Oversight Council. (2012). *Manual for the operation of the Joint Capabilities Integration and Development System*. Retrieved from <https://acc.dau.mil/CommunityBrowser.aspx?id=267116&lang=en-US>
- Kirkwood, C. W. (2002). *Decision tree primer*. Tempe, AZ: Department of Supply Chain Management, Arizona State University.
- Linstone, H. A., & Turoff, M. (1975). *The Delphi method: Techniques and applications*. Boston: Addison-Wesley Publishing.
- Mackay, H., Carne, C., Beynon-Davies, P., & Tudhope, D. (2000). Reconfiguring the user: Using rapid application development. *Social Studies of Science*, 30(5), 737-757.
- Porter, M. E. (1980). *Value chain analysis*. London: Oxford Press Ltd.
- Porter, M. E. (2008). The five competitive forces that shape strategy. *Harvard Business Review*, 86(1), 78-93.
- Ringland, G., & Schwartz, P. P. (1998). *Scenario planning: Managing for the future*. Chichester, UK: John Wiley & Sons.
- Sage, A. P., & Armstrong, J. J. (2000). *An introduction to systems engineering*. New York, NY: John Wiley & Sons.
- Secretary of the Air Force. (2013). *Operational capability requirements development* (AFI 10-601). Washington, DC: Author.
- Shenhar, A. J., & Dvir, D. (2007). *Reinventing project management: The diamond approach to successful growth and innovation*. Boston: Harvard Business Review Press.
- Sink, D. S. (1983). Using the nominal group technique effectively. *National Productivity Review*, 2(2), 173-184.
- Sproles, N. (2002). Formulating measures of effectiveness. *Systems Engineering*, 5(4), 253-263.
- Turner, J. R., & Cochrane, R. A. (1993). Goals-and-methods matrix: Coping with projects with ill-defined goals and/or methods of achieving them. *International Journal of Project Management*, 11(2), 93-102.
- Williamson, O. E. (1979). Transaction-cost economics: The governance of contractual relations. *Journal of Law and Economics*, 22(2), 233-261.

APPENDIX

Additional Analytical Techniques to Assist Initial Capabilities Document (ICD) Writers and Project Managers

Method	Source(s)	Explanation	Usage Context(s)
Pre-Capabilities-Based Assessment (CBA)			
Scenario-based Planning	Capabilities-Based Assessment (CBA) User's Guide, p. 87 (Ringland & Schwartz, 1998) (Hiam, 1990, p. 284)	<p>Technique using scenarios to define/give structure to an otherwise murky strategic future. A type of brainstorming, which may use nominal group technique or another group problem-solving technique.</p> <ul style="list-style-type: none"><li>Assumptions/drivers of change (identify key variables and historical trends)</li><li>Develop framework for drivers</li><li>Produce initial miniscenarios (vary the type: surprise-free, radical, and in-between)</li><li>Reduce to 2 or 3 scenarios</li><li>Write scenarios</li><li>Identify issues arising (sensitivity analysis with scenarios' impact on key variables)</li></ul>	Mostly pre-CBA; used to build portfolios; however, can be used in a CBA (e.g., to analyze threats, etc.).
Strengths, Weaknesses, Opportunities and Threats (SWOT) Analysis	(Helms & Nixon, 2010)	Analyzes internal (strengths/weaknesses) and external (opportunities/threats) factors to help guide corporate strategy development. Useful in a group strategy setting, using nominal group technique, or another group problem-solving technique (like a Group Decision Support System, or GDSS). See also Porter's 5 Forces and Barney's Resource-based View for more specific analyses.	Mostly pre-CBA; used to build portfolios; however, can be used in a CBA (e.g., to analyze threats, etc.). Generally criticized for its lack of depth and rigor.
Porter's 5 Forces Analysis	(Porter, 2008)	Builds on the "threats/opportunities" side of SWOT to explain how market structure, defined by five market forces (threat of entrants, supplier power, buyer power, intensity of rivalry, threat of substitutes) and one additional force (complementors/government/public) drive the content and performance of firms.	Mostly pre-CBA; used to build portfolios; however, can be used in a CBA (e.g., to analyze threats, etc.). Generally criticized for focus on external environment, vice internal.
Barney's Resource-based View (RBV)	(Barney, 1991)	Builds on the "strengths/weaknesses" side of SWOT to explain how a firm's internal resources (value [V], rareness [R], nonsubstitutability [NS], imperfect imitability [I]), lead to sustainable competitive advantage (SCA). $SCA = V + R + NS + I$ Must have first three to achieve competitive advantage, and all four to achieve SCA.	Mostly pre-CBA; used to build portfolios; however, can be used in a CBA (e.g., to analyze threats, etc.). Generally criticized for focus on internal environment, vice external.

Method	Source(s)	Explanation	Usage Context(s)
Pre-Capabilities-Based Assessment (CBA)			
The Project Management Diamond Approach	(Shenhar & Dvir, 2007)	Uses four quadrants of Technology, Complexity, Novelty, and Pace to define the size, scope, and risk of a systems engineering product/project.	Pre-CBA (used to define a product portfolio), CBA/ICD (developing Measures of Effectiveness (MOE), Capabilities Development Document (CDD) (defining system risk).
Market Segmentation Grid	GAO Report No. 07-388, p. 11	A grid that compares four markets (current/new customers in existing segments/customers in new segments/new customer wants and needs) to four offering types (current business/enhancement to current business/new business/new to industry) to position portfolio projects into four categories (strike zone/traditional/pushing the envelope/white space opportunity). A method of analyzing business risk that encourages businesses to find the right mixture of categories of projects. Similar to Risk/Rewards Matrix.	Mostly pre-CBA; used to build portfolios; however, can be used in a CBA.
Risk-rewards Matrix	GAO Report No. 07-388, p. 16 (Hiam, 1990, p. 377)	A grid that plots “risks” vs. “rewards” of projects. Similar to Market Segmentation Grid in that it encourages businesses to find the right mixture of categories of projects. The same tool can be used to compare effectiveness to cost in the AoA “Alternatives Comparison” step (particularly useful in showing confidence levels and threshold values). The “GE matrix” version of this maps “business strength” (internal) vs. “industry attractiveness” (external). The circles may be subdivided into market share/total market pies to enhance analysis. Augments SWOT.	Mostly pre-CBA; used to build portfolios; however, can be used in a CBA. Strength is that the confidence level of estimates is captured (by the size of the circles).

APPENDIX (Continued)

Method	Source(s)	Explanation	Usage Context(s)
Nominal Group Technique	(Sink, 1983)	<p>A brainstorming technique that mixes individual and group activities to attempt to increase the amount, diversity, and quality of ideas generated. Many variations, but follows the basic process below:</p> <ul style="list-style-type: none"><li>• Individual Brainstorming</li><li>• Sharing Ideas</li><li>• Group Brainstorming (divergent)</li><li>• Group Discussion</li><li>• Group Brainstorming (convergent)</li><li>• Voting/ranking</li></ul>	<p>Pre-CBA strategic planning, CBA (developing capabilities/MOE), Analysis of Alternatives (AoA)/ICD/CDD (developing attributes/Key Performance Parameters [KPPs]). Technique strong in generating many diverse ideas without arriving at Groupthink. Other group problem-solving techniques may be superior (e.g., GDSS), but at an increased process cost.</p>
Delphi Technique	(Goodman, 1987)	<p>A type of brainstorming that uses experts to a) identify issues in their area of expertise, b) further define issues in their area of expertise, and c) identify the importance of issues in their area of expertise. Generally uses 3–9 experts, and begins with <i>Nominal Group Technique</i>, using future rounds to refine/reduce/prioritize issues.</p>	<p>CBA ICD (capabilities, MOEs), and AoA/CDD (attributes, KPPs). An example of an “expert” systems analysis technique. Careful choice of experts is essential.</p>
CBA/ICD			
Capabilities-Based Assessment (CBA)	<i>Capabilities-Based Assessment (CBA) User’s Guide</i>	<ol style="list-style-type: none"><li>1) Describes capabilities required to perform a mission</li><li>2) Identifies gaps in capabilities and associated operational risks</li><li>3) Establishes a requirement to address gaps</li></ol>	<p>CBA. Results in an ICD (which not only documents the CBA, but acts as a decision document).</p>
Initial Capabilities Document (ICD)	<i>Capabilities-Based Assessment (CBA) User’s Guide</i>	<ol style="list-style-type: none"><li>1) Describes/summarizes Concept of Operations (CONOPS) (~1 page explanation of CONOPS)</li><li>2) Describes guidance (see <i>Requirements Traceability Matrix</i>)</li><li>3) Describes capabilities required (includes MOEs/threshold values)</li><li>4) Describes capability gaps (prioritized, if possible)</li><li>5) Summarizes relevant threats/operational environment</li><li>6) Proposes nonmateriel and materiel solutions (see <i>Doctrine, Organization, Training, Materiel, Leadership, Personnel, Facilities-Policy [DOTMLPF-P] Analysis</i>)</li><li>7) Final recommendation (normally, but not necessarily, a materiel solution)</li></ol>	<p>CBA/ICD. The ICD is a decision document to further explore an enhanced capability (result of a CBA). Cornerstone document in the Joint Capabilities Integration and Development System (JCIDS) process. Listing to the left is not comprehensive.</p>

Method	Source(s)	Explanation	Usage Context(s)
<b>Requirements Traceability Matrix</b>	Air Force Instruction (AFI) 10-601	Also known as “house of quality,” traces system attributes to operational/user/strategic requirements. Multiple levels.	CBA/MOE (developing capabilities/MOEs), AoA/ICD/CDD (developing system attributes/KPPs).
<b>Paired Comparisons</b>	(Blanchard & Fabrycky, 2010, p. 182)	To build a rank-ordered list, each of the options is presented to the decision maker two at a time (instead of all at once). For $N$ criteria to be ranked, $N(N - 1)/2$ pairs must be compared. Assumes transitivity of preferences.	CBA/MOE/ICD (development of criteria). Rank-ordering importance of design parameters/capabilities/gaps.
<b>Porter's Value Chain Analysis</b>	(Hiam, 1990, p. 415) (Porter, 1980)	<ol style="list-style-type: none"> <li>1) Select unit of analysis, both for your organization and for competitors</li> <li>2) Identify primary value-adding activities (direct/indirect/quality assurance) Inbound/outbound logistics, operations, marketing/sales, service</li> <li>3) Identify support activities (direct/indirect/quality assurance) Procurement, technical development, human resource management, firm infrastructure</li> <li>4) Identify linkages between value chain activities</li> <li>5) Study the value chain to identify sources of competitive advantage</li> </ol>	Pre-CBA, AoA. Much like a <i>DOTMLPF-P Analysis</i> , the value chain requires a gap analysis, but not just internal (between self and competitors), and not just in isolation (focus is on interactions).
<b>Systems Definition Matrix</b>	(Sage & Armstrong, 2000, p. 98)	Applies general systems theory to define both the SCOPE (needs/objectives/criteria) and BOUNDS (parameters/variables/constraints) of a system (e.g., capability, MOEs, attributes, KPPs). No real analytic technique used to define, although defining the SCOPE and BOUNDS of a system can use many of the methods contained herein.	CBA/ICD (capabilities, MOEs), and AoA/CDD (attributes, KPPs). See also Work/Product Breakdown Structure (WBS/PBS) for a technique to develop the initial listing of attributes.
<b>Input-Output Matrix</b>	(Sage & Armstrong, 2000, p. 102)	Applies general systems theory to define inputs (intended/unintended) and outputs (desired/undesired) and begin a more sophisticated discussion about refining a system, such as: situation, expertise, risk, spillover effects, knowledge, viewpoints, experience, kind of need, frequency, urgency, limits, and tolerances. As shown in Sage, uses a WB structure, but could also use a PB structure.	CBA/ICD (capabilities, MOEs), and AoA/CDD (attributes, KPPs).

APPENDIX (Continued)

Method	Source(s)	Explanation	Usage Context(s)
<b>Rapid Application Development (RAD)</b>	(Mackay, Carne, Beynon-Davies, & Tudhope, 2000)	<p>RAD uses short, iterative design cycles to produce working prototypes and systems. A mixture of paper prototypes (e.g., the different Department of Defense Architecture Framework [DoDAF] views, use cases, screen shots), code stubs I menus, and models may all be used. Many types, including:</p> <ul style="list-style-type: none"><li>• Joint Analysis and Design (JAD): ½-day sessions placing developers and users together. Developers use the rest of the day to build prototypes. Lasts approximately 1 week.</li><li>• eXtreme: exploration consists of users writing story cards (use case), which developers analyze and give estimates to complete. Business then prioritizes the cards by usefulness and developers prioritize by risk. Best mix of cards selected to implement.</li></ul>	Usually used when implementation is more important than documentation; however, the process of idea generation and documentation makes this technique ideal for pre-CBA and CBA activities. Technique may also be used in early systems engineering (SE) to help define systems (assumes that many users do not “know what they want until they see it”).
<b>Use-cases</b>	<i>Capabilities-Based Assessment (CBA) User’s Guide</i> , p. 87	A use-case may be as broad as a story outlining how a system would be used in an ideal circumstance (or multiple circumstances), or might be as specific as a Unified Modeling Language (UML)-based diagram outlining a specific system interaction that can be used to generate an engineering prototype. Many ICDs iterate 1-4 possible “scenarios for use,” with the resulting scenarios resembling SE use-cases.	Normally post-CDD; however, technique useful in early SE. See Scenario-based Planning for a similar technique applied to large-scale planning.
<b>Intelligence-based Assessment</b>	Existing ICDs	Used either to further define a capability gap, or to further define the “threats/operational assessment” category, this item usually lists the threat as defined by current intelligence assessments, as well as the reference for the applicable intelligence assessment.	Pre-CBA, CBA, ICD. Analysis type is present in Operations Plan/Concept of Operations Plan (OPLAN/CONPLAN), so it helps trace operational requirements/gaps to those documents.
<b>Work/Product Breakdown Structure (WBS/PBS)</b>	(Turner & Cochrane, 1993)	May be defined from top-down (decomposition), or bottom-up (engineering). Begin with major items, and continually ask “what comes next,” or “what is this component/objective made of.” Stop when either: 1) you know how to measure (objectives) or 2) a reasonable amount of work (i.e., “work package”). “Decomposition” risk is that not all end items are identified, leading to inaccurate estimate. Engineering risk is in omitting important integration items, or nonproduct-related tasks (i.e., Project Management).	CBA/MOE (developing criteria), AoA/ICD/CDD (system definition). Used to decompose requirements or work hierarchically. May then be used for the basis of defining/estimating work, cost, MOE, or other decision objectives/criteria.

Method	Source(s)	Explanation	Usage Context(s)
<b>Measure of Effectiveness (MOE) Definition</b>	(Sproles, 2002, p. 255)	<ul style="list-style-type: none"> <li>• Request to formulate MOEs</li> <li>• Determine viewpoint</li> <li>• Determine mission</li> <li>• Decide on Critical Operational Issues (COI), i.e., “tasks/categories”</li> <li>• Draft MOEs (creative/testable/consistent with library/statement)</li> <li>• Evaluate/Revise/Agree on MOEs</li> <li>• Apply MOEs</li> </ul>	CBA/ICD. MOEs are normally high-level, and one might expect 10–20 of them in an ICD, whereas a CDD might contain hundreds of KPPs. Modern ICDs will usually contain MOEs as well as threshold values.
<b>Requirements Correlation Table</b>	<i>Manual for the Operation of the JCIDS</i> , 2012, p. B-31; AFI 10-601, p. 37	<p>Summary of all desired capability characteristics listed as <i>threshold/objective</i> values, mapped to their Joint Capability Area (JCA). Three tables: Key Performance Parameters (KPPs), Key System Attributes (KSAs), Attribute. Each table has a brief explanation of derivation/justification of attributes listed.</p> <ul style="list-style-type: none"> <li>• KPP: System attributes considered most critical or essential for an effective military capability. Failure to meet KPP threshold may result in program reevaluation/reassessment.</li> <li>• KSA Table (AF-only): Only the most critical system attributes are included and <i>prioritized</i>.</li> <li>• Additional Attribute: Same as KSA, but contains additional items.</li> </ul>	ICD/CDD. Helps decision makers and acquisition community decide on most important attributes, and the threshold I objective values those items must exhibit. Note that JCAs, listed in the <i>Manual for the Operation of the JCIDS</i> , p. B-B-1, can be used to assist in attribute definition as early as the CBA process, as well as to derive KPPs from JCAs.
<b>Capability Gap Matrix</b>	Existing ICDs	Perhaps the most common table arising since 2008 in ICDs, this table lists (in the following order): Priority, Capstone Concept for Joint Operations (CCJO) Key Characteristics, Capability, JCAs, Parameters/Measures of Effectiveness, and Minimum Value (for Parameters). Answers many key questions, and may be combined with a capability gap matrix. See Requirements Correlation Table and Capability Gap Pairwise Matrix.	CBA, ICD. This table combines capabilities, MOEs, and minimum values. It does not directly address capability gaps (unless gaps are incorporated).

APPENDIX (Continued)

Method	Source(s)	Explanation	Usage Context(s)
Capability Gap Pairwise Matrix	Capabilities-Based Assessment (CBA) User's Guide, p. 89; Existing ICDs	A method of prioritizing capability gaps with respect to each other by pairwise comparison (using correlation matrix). Each capability is listed both on the rows and the columns, and compared to others (1.00 is "the same as," while 0.00- .99 is "less than," and 1.01- > is "greater than"). The relative weight of items to each other is multiplicative (with 2.00 being "twice as important as"). Scores are summed across rows (and normed, if desired), and then rank-ordered based on the scores, with a higher score being more important. Note: One variation uses "stoplight" (i.e., Red, Yellow, Green) to highlight the degree to which an attribute (column) represents a "gap" with current key UJTL, JCA, etc. tasks (tuple).	CBA. Technique also useful to rank-order MOEs (ICD) and/or criteria (AoA/CDD). See <i>Pairwise Comparison</i> for a similar technique exploring the same questions (uses transitivity to justify using fewer comparisons). Scores, rankings, and "stoplight" symbols are qualitative measures, assigned at the discretion of the ICD team.
DOTMLPF-P Analysis	Capabilities-Based Assessment (CBA) User's Guide; Manual for the Operation of the JCIDS	Any analysis that includes the following factors (and their potential interactions): Doctrine, Organization, Training, Materiel, Leadership Policy and Education, Personnel, Facilities, and Policy. Important to consider in all phases of early systems analysis, including: a) Gap analysis (CBA), b) nonmateriel solution (CBA—most typical use), c) nonmateriel enablers to materiel solution (CBA and/or CDD).	CBA/MOE (developing capabilities/MOE), AoA/ICD/CDD (developing/rating system Attributes/KPPs). See DOTMLPF-P Matrix.
DOTMLPF-P Matrix	Existing ICDs	A matrix showing capability gaps and/or objectives down tuples and Y/N/P answers to DOTMLPF-P on each column, with a "rationale/comments" column. Y = gap may be resolved without materiel development N = no solution currently exists P = partial solution exists	CBA /ICD/AoA/CDD. This version of the matrix is tailored toward gap analysis, specifically. May have other uses; see DOTMLPF-P Analysis.
Cross-interaction Matrix	(Sage & Armstrong, 2000, p. 110)	A correlation matrix showing the interactions between system objectives (as shown, uses ordinal "+," "0," and "-" to show interactions, but could also use scalar <i>Capability Gap Matrix Measures</i> ).	CBA/ICD (capabilities, MOEs), and AoA/CDD (attributes, KPPs).
Frequency/Investment Matrix	(Williamson, 1979)	Recurrent or occasional, but nonspecific market transactions are best handled by classical (market) contracts. The tendency toward recurrent and idiosyncratic transactions tends to favor unified governance. May also explain boundary of firm, vertical integration, and departmentalization (consideration for funding CBA work via contracts).	Used to determine type of contract one might use to purchase different types of services on the market. Uses transaction costs (immeasurable) as theoretical mechanism to explain.

Method	Source(s)	Explanation	Usage Context(s)
AoA/CDD			
<b>Analysis of Alternatives (AoA)</b>	AFI 10-601; AoA Handbook, pp. 14, 31, 33, 45, 46, 47	<p>The AoA is a process, consisting of four basic sections: 1) Effectiveness Analysis, 2) Cost Analysis, 3) Risk Analysis, and 4) Alternative Comparison. Each of these four items uses techniques such as <i>Decision Evaluation Matrix</i> to evaluate alternatives based on MOEs. MOEs may be mapped to their overarching tasks or desired outcomes.</p> <ul style="list-style-type: none"><li>• Effectiveness Analysis: 1) Select Mission Tasks (MT), MOE, and MOPs, 2) Select threats/scenarios, 3) Describe alternatives, 4) Determine level of detail, 5) Identify suitable analysis tools/data sources (consider including sensitivity analysis)</li><li>• Cost Analysis: 1) sunk, 2) research and development, 3) investment, 4) operating/support, 5) disposal, 6) baseline extension, 7) prefielding</li><li>• Risk Analysis: see <i>Risk Analysis</i></li><li>• Alternative Comparison: see <i>Decision Evaluation Matrix</i> and <i>Risk-Rewards Matrix</i>. The AoA Handbook shows a <i>Decision Evaluation Matrix</i> with additional columns (for risk and cost).</li></ul>	AoA/ICD (developing and applying MOE to capabilities), CDD (developing and applying criteria to alternatives). The items used to BOUND the AoA are same items used to BOUND the ICD. AoA Handbook gives guidelines for performing the steps, overview of analysis tools, and modeling suggestions. Finally, AoAs need not identify a single solution (in fact, they may identify a suite of solutions that meets certain requirements).
<b>Decision Evaluation Display</b>	(Blanchard & Fabrycky, 2010, p. 187)	Graphical representation of: 1) alternatives (A, B, C); 2) equivalent cost/profit; 3) other criteria (X, Y, Z). Although not strictly a 2-dimensional view, the x-axis is structured according to increasing cost/profit of alternatives, and the y-axis is scaled with relative (ordinal, i.e., less than, equal to, more than) achievement by alternatives of the criteria. (Note: Normally, these would be separate graphs for each criteria, but they are stacked on top of each other to simplify the display, with no implication of relevance of the different position of each criterion on the y-axis [except with reference to itself]).	CBA/MOE (developing criteria), AoA/ICD/CDD (applying criteria). Organizes information on alternatives and degree of compliance with criteria (including threshold values) while still allowing for decision-maker insight, intuition, and judgment. Not intended to be mathematically applied.

APPENDIX (Continued)

Method	Source(s)	Explanation	Usage Context(s)
Decision Evaluation Matrix	(Blanchard & Fabrycky, 2010, p. 189)	<p>A matrix with alternatives on the x-axis (as a <i>tuple</i>), and three items on the y:</p> <ul style="list-style-type: none"><li>Header #1: a future not under the control of the decision maker ("state of nature")</li><li>Header #2: the probability (<i>p</i>) of that future</li><li>Each cell: evaluation (<i>E</i>) measure (positive or negative) of [alternative x future]; may be subjective (i.e., categorical) or objective (e.g., monetary values)</li></ul> <p>Possible decision-making criterion (to select most desirable alternative):</p> <ul style="list-style-type: none"><li>Aspiration level: setting desired <i>min</i> and <i>max</i> levels for each criterion, or for all criteria as a whole</li><li>Most probable future: useful if one probability dominates</li><li>Expected value (EV): <math>EV = \sum(E \times p)</math> where <math>\sum p = 1.00</math> useful for repetitive environment<ul style="list-style-type: none"><li>Laplace: if <i>p</i> unknown for each alternative, divide 1.00 by number of alternatives</li><li>Maximin: <i>best</i> alternative given the <i>worst</i> possible outcome</li><li>Maximax: <i>best</i> alternative given the <i>best</i> possible outcome</li><li>Minimax (includes "regret"): <i>best</i> outcome<ul style="list-style-type: none"><li>outcome for "<i>a<sub>j</sub></i>" / "<i>s<sub>j</sub></i>"; attempts to calculate opportunity cost of a decision</li></ul></li><li>Hurwicz rule: assigns an optimism index from 0-1.0 (assumes linearity)</li></ul></li></ul>	<p>CBA/MOE (developing criteria). AoA/ CD/ DD (applying criteria). Considers alternatives/ criterion of effectiveness in past/present, but also alternatives/possible future conditions [of use]. Assumes: all viable alternatives considered, all possible futures identified, all futures and [alternatives x futures] are orthogonal, occurrence of specific future is unknown (otherwise, matrix simplifies to a vector of evaluation measures). Limitation: each of these methods yields different results.</p>
Decision Tree	(Kirkwood, 2002)	<p>Calculates an expected value (EV) for each of a number of possible options, exploring what happens if selection leads to success or failure. May include a "none of the above" option. One common use is to include, add together the cost of each of the options with their expected payout to generate the evaluation (<i>E</i>) measure.</p> <ul style="list-style-type: none"><li><math>EV = \sum(E \times p)</math>, where <math>\sum p = 1.00</math> for the outcome of each decision. Most useful for repetitive environment; otherwise, the EV metric has no inherent meaning (although often shown as monetary value, \$).</li></ul>	<p>CBA/CD/AoA/CDD. Amenable to monetary decisions that can be stated in Boolean (success/failure) terms. Options must be orthogonal. May also be used to model multiple, sequential decisions. See <i>Decision Evaluation Matrix</i> for an additional application of this technique.</p>

Method	Source(s)	Explanation	Usage Context(s)
<b>Optimization Modeling/Linear Programming</b>	(Blanchard & Fabrycky, 2010, p. 177)	$E = f(X, Y_d, Y_i)$ $X$ = Design variables (factors that define design optimization space) $Y_d$ = Design-dependent variables (under control of designers) $Y_i$ = Design-independent variables (not under designer-control)	CBA/MOE (developing criteria), AoA/ICD/CDD (applying criteria). Determining effectiveness of a system based on a model of that system including the most relevant variables. Models lack of certainty due to factors not under designers' control. See <i>Decision Evaluation Matrix</i> for an additional application of this technique.
<b>"Scorecard" Matrix</b>	(Sage & Armstrong, 2000, p. 111)	Yet another technique to compare alternatives to criteria, this time with the emphasis on technology maturity alternatives (see <i>Market Segmentation Grid</i> ) crossed with the "-ilities"—although any combination thereof with other techniques in this listing could be used.	CBA/ICD (capabilities, MOEs), and AoA/CDD (attributes, KPPs).
<b>Utility (Indifference) Curves</b>	(Brosh, 1985, p. 70)	Having developed a decision tree with monetary outcomes (but not yet assigned probabilities of outcomes), it is possible to query the decision maker as to the amount deemed acceptable as a guaranteed payout instead of accepting the probabilities of payouts represented in the decision tree. Varying the probabilities and re-asking this question allows one to create a utility curve, with the payout on the x-axis and utilities on the y-axis. The "risk-neutral" decision maker's utility curve is negative first derivative (positive, but decreasing), while the "risk-averse" is a positive first derivative (positive, but increasing).	Answers question of decision maker's risk-averse/neutral/seeking nature, i.e., is valuation of marginal utility of money decreasing/constant/increasing? Determines whether to use <i>minimin</i> , <i>minimax</i> , <i>maximax</i> . Paired with <i>Decision Evaluation Matrix</i> to model alternative preference in terms of "utility" vice "monetary."
<b>Weighting</b>	(Blanchard & Fabrycky, 2010, p. 185)	Weights (W) must sum to 1.00 (100%) for each criterion. Ratings (R) based on whatever <i>scalar</i> rating schema one devises (does not work for ordinal/categorical ratings). $Weighted\ Rating = W \times R$ <ul style="list-style-type: none"> <li>• Tabular display: results indicate how close each alternative comes to the <i>ideal</i>.</li> <li>• Graphical additive: results indicate the overall contribution of the rating in each category to the overall desirability of the alternative.</li> </ul>	CBA/MOE, AoA/ICD/CDD. Choosing across a number of design alternatives when categories are not of equal importance (see <i>systematic elimination</i> for similar method). Caution is advised in developing both criterion and weighting, as well as in interpreting two alternatives that end up rating near each other on the scale.

APPENDIX (Continued)

Method	Source(s)	Explanation	Usage Context(s)																																				
<b>Z-score Transformation</b>	(Daszykowski, Kaczmarek, Vander Heyden, & Walczak, 2007)	For items collected using ratio/continuous data for which an expected value (mean) and dispersion (standard deviation) are known, application of a z-transformation can re-score an item (results in a number between -1.0 and +1.0). Items can then be further transformed by <i>weighting</i> or another technique and be comparable across different items (e.g., “time-to-implement” vs. “distance”).	AoA.																																				
<b>National Family Opinion (NFO) Product Analysis</b>	(Hiam, 1990, p. 273)	<p>1) Survey customer attitudes to obtain rankings of importance of product attributes and a rating of the overall product (Likert-type scale: 5-point, -2 to +2). Likert scales are commonly used in surveys to measure attitudes.</p> <p>For example: My current level of job satisfaction is:</p> <table><tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td></tr><tr><td></td><td>Extremely</td><td></td><td></td><td></td><td></td><td>Extremely</td></tr><tr><td></td><td>Unsatisfied</td><td></td><td></td><td></td><td></td><td>Satisfied</td></tr></table> <p>or in the case of the NFO Product Analysis: How well does the product meet the desired attribute (x)?</p> <table><tr><td>-2</td><td>-1</td><td>0</td><td>+1</td><td>+2</td></tr><tr><td>Not nearly</td><td></td><td></td><td></td><td>Far too</td></tr><tr><td>enough of x</td><td></td><td></td><td></td><td>much of x</td></tr></table> <p>2) Use stepwise linear regression to determine most important attributes to overall ratings (calculate <math>R^2</math>, then “Importance Index”: <math>R^2_{ind} / R^2_{tot}</math>).</p> <p>3) Graph the “importance index” vs. mean ratings for each attribute. Items on upper corners are those worth investing effort into.</p>	1	2	3	4	5	6	7		Extremely					Extremely		Unsatisfied					Satisfied	-2	-1	0	+1	+2	Not nearly				Far too	enough of x				much of x	AoA. A method like this compares the perceived “gap severity” with the “importance” of an attribute in order to assist the researcher in prioritizing the attributes.
1	2	3	4	5	6	7																																	
	Extremely					Extremely																																	
	Unsatisfied					Satisfied																																	
-2	-1	0	+1	+2																																			
Not nearly				Far too																																			
enough of x				much of x																																			
<b>Systematic Elimination</b>	(Blanchard & Fabrycky, 2010, p. 183)	<p>Do not consider <i>weights</i>, nor <i>trade-offs</i> across alternatives. May use scalar or categorical ratings.</p> <ul style="list-style-type: none"><li>• Compare alternatives against each other (norm-referencing: will establish dominance between two options [drop the lower one]).</li><li>• Compare alternatives against a standard (criterion-referencing: 1) retaining if meets standard for at least <i>one</i> criterion, or 2) retaining if meets standard for <i>all</i> criterion).</li><li>• Comparing criteria across alternatives (after <i>ranking</i> criterion: 1) choose best alternative, break ties with the second most important criterion, or 2) examine one criterion at a time, comparing the alternatives and eliminate those not meeting minimum standard).</li></ul>	CBA/MOE (developing criteria), AoA/ICD/CDD (applying criteria). Choosing across a number of design alternatives. Outcomes can be specified for all criteria and alternatives. May use to select best option, or to determine which of a number of options meet minimum criteria for further inclusion. See <i>weighting</i> for another similar method.																																				

Method	Source(s)	Explanation	Usage Context(s)
<b>Sahid's Consequences Table</b>	(Hammond, Keeney, & Raiffa, 1998)	Lists alternatives across the columns and key attributes/decision criteria down tuples. The goal of this table is not to combine disparate data types, but rather to search for options that clearly "dominate" other options. The "dominated" options are then eliminated systematically.	AoA. Because it is an initial screening process, it reduces options/simplifies choice; however, ensure the most important attributes are screened first.
<b>Even Swaps</b>	(Hammond, Keeney, & Raiffa, 1998)	A more sophisticated analysis using <i>Sahid's Consequences Table</i> , "how much of one attribute are you willing to swap for an increase/decrease in the other?" In this way, attributes of key interest can be made comparable by trading up/down other attributes. This is one form of <i>sensitivity analysis</i> .	AoA. Does not treat alternatives as exclusive; encourages decision maker to look for (not listed) alternatives to satisfy "swapped" items.
<b>Risk Analysis</b>	<i>AoA Handbook</i> , p. 40	Risks are categorized by Severity ( $S$ , i.e., consequence) and Probability ( $p$ , e.g., likelihood). If each risk is assigned a number from 0.00 - 1.00 for both categories, then a composite risk index can be calculated using: $CR = S \times p$ , and a risk matrix can be used to plot the results. Risk may then be avoided, accepted, transferred, and/or mitigated. Some add three columns to a risk table to add how the risk was managed, the resultant risk, and any secondary risks that risk mitigation created.	AoA. Technique uses qualitative assignment of risk values. Normally, risks are assumed orthogonal (however, risk interactions can be modeled with this technique).
<b>Sensitivity Analysis</b>	(Blanchard & Fabrycky, 2010, pp. 589, 614)	A generic category of tools that plots/graphs/calculates the relationship between changing variables, giving an idea of how a modification in one variable affects others. Plotting different alternatives on the same axis gives an idea of the favorability of one option versus the other in the trade space measured (a.k.a. the "breakeven point"). Examples: Pareto chart (a line or bar graph displaying results ordered by frequency of occurrence), scatter plot, cost/year plot.	Primarily AoA/CDD, but can be used in CBA/ICD.
<b>Cost Breakdown Structure (CBS)</b>	(Blanchard & Fabrycky, 2010, p. 577)	Similar to a WBS/PBS, a CBS breaks all costs down, either by product, cost center, or development phase. Blanchard and Fabrycky call this a "functional" breakdown). A typical CBS might include items such as: research and development cost, production/construction cost, operations and maintenance cost, retirement and disposal cost. Many of the cost categories included in a CBS are standardized items in the finance community, and each has estimation technique(s) associated with it. Costs are often captured on a <i>Cost Collection Worksheet</i> .	AoA/CDD. The U.S. military does not normally perform some of the key items included in a CBS; therefore, estimates in these areas may not be reliable (or else the military might contract the cost estimate).

APPENDIX (Continued)

Method	Source(s)	Explanation	Usage Context(s)
Cost Collection Worksheet	(Blanchard & Fabrycky, 2010, p. 586)	Basic mechanism used to gather and report costs generated by a CBS. Much like a WBS, costs are broken down by function and subfunction (and the associated cost categories) in the tuples, while the cost by program year, total (actual), total net present value and % contribution are in columns.	AoA/CDD. Compares programs by cost center/year, or cost profile (since profile by center/year is accessible to viewing).
Parameter-based Costing	(Blanchard & Fabrycky, 2010, p. 581)	One of the four types of cost estimating, parametric analysis, involves determining key parameters that drive cost (historically), then using these parameters to estimate future costs.	AoA/CDD. Only as good as past information and current judgment.
Activity-based Costing	(Blanchard & Fabrycky, 2010, p. 581)	A method directed toward “detailing and assignment of all costs to the activities that cause them to occur,” in an effort to include traceability (for items historically difficult to track; i.e., indirect costs like “overhead”).	AoA/CDD. May be at odds with WBS/PBS methods of tracking costs (because functions like project management spread across multiple cost centers).
Life-cycle Cost Summary	AoA Handbook, p. 37	Breaks out life-cycle costs two ways: 1) by alternative and life-cycle phase, 2) by budget category and life-cycle year (any combination of these is acceptable, based on the requirement).	AoA.
Money Flow Modeling	(Blanchard & Fabrycky, 2010, p. 176)	Considers present equivalent (PE), annual equivalent (AE), or future equivalent (FE) amount, as well as internal rate of return and payback period. $PE, AE, \text{ or } FE = f(F_t, i, n)$ $t = 0, 1, 2, \dots, n$ (salvage value/cost added at end of final year) $F_t = \text{positive or negative money flow at end of year } t$ $i = \text{annual interest rate}$ $n = \text{number of years}$	ICD/AoA/CDD (economic AoAs). Calculating outlay and payback of a system over its acquisition and utilization. See <i>Decision Evaluation Matrix</i> for an additional application of this technique.